AIRS/AMSU/HSB Version 7 Level 2 Quality Control and Error Estimation

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1 Introduction

The AIRS/AMSU/HSB Level 2 (L2) Standard Products contain many retrieved parameters, and each has an associated quality indicator the researcher should use to filter and subset the specific geophysical parameter of interest. Each retrieved physical quantity also has its own matching error estimate. The names of the quality indicators are the same as the name of the corresponding parameter with "_QC" appended to the name, for example **TAirStd_QC**. The error estimates have the name of the parameter with "Err" appended, for example an array named **TAirStdErr**.

This document contains a description of the quality indicators, what their values mean, and how they are set for different types of retrievals (IR-Only, Combined IR/MW or MW-only) and different products. Also, it is described how errors are estimated for a given geophysical quantity, how pressure boundaries within a given profile are associated with quality (**PBest** and **PGood**) and how they are set based on error estimates.

1.1 IR-Only and Combined MW/IR Retrieval Data Sets

The baseline system in Version 7 (V7) is an IR-only physical retrieval preceded by an IR/MW neural network using the remaining usable AMSU channels. An IR/MW physical retrieval is no longer possible because insufficient channels remain available to characterize the microwave surface emissivity accurately.

A second flavor of the retrieval system is the Combined MW/IR processing, which is similar to the mainline Version 6 (V6) processing prior to the failure of AMSU channels 1 and 2 in 2016. The combined and microwave products are thus unavailable beyond fall 2016. However, reprocessing will occur prior to that date of the combined system. **Researchers should never combine MW/IR and IR-Only retrievals in their analyses, for the statistical sampling and quality of the two data products are different.** We recommend the use of one or the other, but never both combined.

1.1.1 Failure of HSB and AMSU Channels

- HSB (scan mechanism) failed on 5 February 2003
- AMSU Channel 4 NeDT exceeded 1 K late in September 2007 and rose sharply thereafter. It was excluded from V5 processing on 1 Oct 2007.
- AMSU Channel 5 NeDT exceeded 1 K early in January 2011 and rose above 2 K in December 2011. It was never excluded in V5 Processing.

- AMSU Channel 7 exhibited excessive noise at launch and was never used in any version of the physical retrieval.
- AMSU Channels 1 and 2 failed on September 24, 2016, and are no longer operational.
- AMSU Channel 14 showed anomalous behavior from June 20, 2018, to June 19, 2019, but now is operating normally.
- AMSU Channel 6 shows increasing an increasing noise trend. It is still below 1 K but is likely to exceed that threshold in 2020 or 2021.

For continuity throughout the mission, V7 mainline processing uses only AMSU channels 3 and 8-13 in the neural network and no AMSU channels in the physical retrieval. AMSU+AIRS processing through 2016 does not use radiances of AMSU channels 4 and 5. On the other hand, V6 AMSU+HSB+AIRS processing DOES use radiances of AMSU channels 4 and 5 to provide maximum quality retrievals, particularly for moisture.

2 Level 2 Quality Indicators

2.1 Quality Indicators Overview

AIRS/AMSU/HSB data users can always find a *_QC variable the same shape as the retrieved variable they're looking at. Users should generally only use data with quality indicator values of 0 or 0 and 1 combined, depending on how they want to trade-off yield vs. accuracy. The possible values for the quality indicators of L2 products are:

Quality = 0 => "BEST"
Data products individually meet our accuracy requirements and may be used for comparison with in situ measurements, data assimilation and statistical climate studies.

Quality = 1 => "GOOD"
Data may be used for statistical climate studies, as they meet the accuracy requirements only when temporally and/or spatially averaged. Note that relying solely on Quality = 0 cases when generating monthly mean fields may result in significant sampling biases. Users may find it useful to compare the number of times the field was observable with the number of retrievals of that field over the sampling period.

Quality = 2 => "DO NOT USE"
While we do not recommend use of any Quality = 2 data, we recognize that it may be the only data available in the vicinity of hurricanes and storm fronts. Users should carefully check the error estimates on the individual soundings and proceed with great caution if they contemplate making use of these data

We create our Level 3 products by combining Quality = 0 and Quality = 1 data, averaged over the appropriate spatial area (1°x1° grid) and time period (daily and calendar month).

Retrieved parameters are generated for each Field of Regard (AMSU Field of View). If satisfactory infrared cloud cleared radiances cannot be produced, all surface and atmospheric retrieval products are flagged Quality = 2 (do not use).

Quality indicator pressure boundaries, **PBest** and **PGood,** are provided for all retrievals. Whenever the IR retrieval is completed, many parameters, including stratospheric temperature, are marked Quality = 0 at high altitudes. At some level in the atmosphere the temperature profile error estimates may exceed a threshold, and **PBest** is set to that pressure level. Deeper in the atmosphere the error estimates may exceed a larger threshold and **PGood** is set to that pressure level. The surface and atmospheric retrieval products are then flagged as described in the remainder of this document. More details of the algorithmic flow can be found in the document **V7_L2_Retrieval_Flow.pdf** (available at https://disc.gsfc.nasa.gov/information/documents?title=AIRS%20Documentation).

Users are encouraged to use PBest and PGood for temperature and water vapor if it simplifies their analysis. However, users should not use levels below the surface (P > PsurfStd) in any spatial averages. These values below the surface are present only to enable vertical interpolation near the surface in individual profiles by representing the lapse rate in the lowest partial level of the atmosphere.

If clouds can be obtained from the startup state, the cloud related products including outgoing longwave radiation (OLR) and precipitation estimate are flagged Quality = 2. If the retrieved surface temperature differs from the first guess (provided by the neural net) surface temperature by five degrees or more, the surface parameters are marked Quality = 2 and the clouds and OLR are computed from the neural net surface combined with the IR/MW retrieved atmosphere. The OLR and clouds are marked Quality = 1 for these cases.

For Version 7, the baseline system is an AIRS-Only physical retrieval preceded by a neural network which uses channels which are still stable as of early 2020 (channels 3 and 8-13). AIRS/AMSU retrievals will be produced as a separate product up to the time that AMSU channels 1 and 2 failed.

Several modifications have been made to the quality control between Version 6 and Version 7. For atmospheric temperature and water vapor, they are not conceptual changes but have been designed to improve the quality of the retrieval in the boundary layer by better discriminating among cases. Some decision points were moved to different layers and some numerical threshold points changed. One relative humidity quality check was modified. And ozone now has its own quality control. Further details of these changes are described in Appendix I.

2.2 MW-Only Retrieval Quality Indicators

These are available ONLY in the IR/MW combined processing available until September 24, 2016.

2.2.1 MW-Only Temperature Profile Quality Indicators

Standard product:

TAirMWOnlyStd_QC
sfcTbMWStd_QC
EmisMWStd_QC

Support product:

TAirMWOnly_QC

The part of the **TAirMWOnlyStd** profile at pressures equal to or greater than 201 hPa is set by examining the bits in **MW_ret_code** corresponding to tropospheric temperature channels (AMSU channels #5 through #8) to detect:

- Excessive residuals
- Excessive liquid water (> 0.5 kg/m_2)
- Insufficient valid channels
- Numerical error
- Emissivity not within the interval [0,1] for any AMSU-A channel

If any of these five bits are set, then **TAirMWOnlyStd_QC** and **TAirMWOnly_QC** for those levels are set to Quality = 2; otherwise they are set to Quality = 0. **sfcTbMWStd_QC** and **EmisMWStd_QC** are also set by this check, with the additional modifications that in the absence of HSB, array elements 6 and 7 (corresponding to 150 GHz and 183.31 GHz) are marked Quality = 2 and contain fill values (-9999). In the absence of radiances from AMSU channels 4 and 5, array element 4 (corresponding to 52.8 GHz) contains values for both **sfcTbMWStd** and **EmisMWStd,** but **sfcTbMWStd_QC(4)** is set to Quality = 2 to reflect the absence of an actual measurement here.

The part of the**TAirMWOnlyStd** profile at pressures less than 201 hPa is set by examining the bits in **MW_ret_code** corresponding to stratospheric temperature channels (AMSU channels #9 through #14) to detect:

- Excessive residuals
- Insufficient valid channels
- Numerical error

If any of these three bits are set, then **TAirMWOnlyStd_QC** and **TAirMWOnly_QC** for those levels are set to 2; otherwise they are set to 0.

Thus, for these two quality indicators:

0 = associated profile segment accepted

1 … never occurs

2 = associated profile segment rejected, researchers should not use

2.2.2 MW-Only Moisture Profile and Cloud Liquid Water Quality Indicators

Standard product:

totH2OMWOnlyStd_QC
totCldH2OStd_QC

Support product:

H2OCDMWOnly_QC
GP_Height_MWOnly_QC
lwCDSup_QC

These quality flags are set according to the V5 rules for **Qual_MW_Only_H2O,** which is no longer output in V7. The failure of HSB degraded various moisture research products, and this quality factor is set in part by the availability of HSB data. It is set by examining the bits in **MW_ret_code** for channels affecting the moisture retrieval to detect:

- Excessive residuals
- Excessive liquid water (> 0.5 kg/m2)
- Insufficient valid channels
- Numerical error
- Emissivity not within the interval [0,1] for any AMSU-A channel

If any of these five bits are set, then these quality flags are set to 2.

If the test on **MW_ret_code** yields no fault, an additional test is performed. If HSB data are present these quality flags are set to 0. If HSB data are not present and **MWSurfClass** = 0 or 2, these quality flags are set to 1, and they are set to 2 for all other surface types. Note that quality = 1 here constitutes the best level of quality that can be achieved when HSB data are not available.

The quantity **GP_Height_MWOnly** depends on both temperature and water, working upward from the surface. **GP_Height_MWOnly_QC** for the entire profile is set to the higher of **TAirMWOnly_QC(surface)** or **H2OCDMWOnly_QC(surface)**.

Users should filter MW-Only moisture retrievals according to these quality values as follows:

0 = (i.e., HSB data used) use column totals and support product profiles

1 = (i.e., HSB data not used) use only the column totals

2 = moisture retrieval rejected, do not use

2.3 IR-Only and Combined IR/MW Retrieval Quality Indicators

2.3.1 Profile Quality Indicator

In V7 (as in V6), two characteristic pressures are determined that define the quality of the temperature profile of an accepted IR/MW retrieval. While determined by the temperature retrieval error estimates, these values are also applied to the water profiles:

- **PBest:** The profile from the top of the atmosphere (TOA) to this pressure level is of best quality (i.e., Quality = 0).
- **PGood:** The profile beneath the level of **PBest** down to this pressure level is of good quality (i.e., Quality = 1). The temperature profile beneath the level of **PGood** is assigned Quality = 2 (do not use). Note that **PBest** and **PGood** may be identical. In this case the temperature profile for altitudes above and including that pressure level is assigned Quality = 0 whereas the temperature profile for altitudes below that pressure level is assigned Quality = 2.
- **nBestStd**: The index of the lowest altitude level of the **pressStd** and **TAirStd** profiles for which the quality is “best”. Levels whose indices are in the range i = **nBestStd**, 28 are therefore marked Quality = 0. It is set to a value of 29 to indicate that none are “best”. Take note that **nBestStd** is 1-based (as are arrays in FORTRAN and MATLAB) rather than 0-based (as are arrays in C, IDL and Python).
- **nGoodStd:** The index of the lowest altitude level of the **pressStd** and **TAirStd** profiles for which the quality is “good”. Levels whose indices are in the range i = **nGoodStd**., **nBestStd**-1 are therefore marked Quality = 1. It is set to a value of 29 to indicate that none are “good”. Take note that **nGoodStd** is 1-based (as are arrays in FORTRAN and MATLAB) rather than 0-based (as are arrays in C, IDL and Python).

Corresponding values **nBestSup** and **nGoodSup** for the support levels are found in the support product, and they are each set to a value of 0 to indicate that none are “best” or “good” respectively.

Users should take note that the indices of the levels and layers of profiles in the standard product increase from surface to TOA (i.e., index 20 is at lower altitude than index 21); conversely, the indices of the levels and layers of profiles in the support product increase from TOA to surface (i.e, index 50 is at higher altitude than index 51).

Users should also note that the level below the surface (PSurf) may contain data marked valid. This data value is only to be used for vertical interpolation through the atmospheric layer including the surface and is not intended for direct use in making spatial averages.

The methodology for determining **PBest** and **PGood** is discussed in detail in Section 3 of this document.

In all cases, the quality for temperature profile levels at p > **PGood** is assigned Quality = 2 (do not use).

2.3.2 Important Note Concerning Contamination due to Dust and Volcanic Ash

Physical retrievals can be seriously compromised if the AIRS field of regard is contaminated by dust and/or volcanic ash. Users should always include the **dust_flag**, **dust_score** and **BT_diff_SO2** in their quality control filtering of data.

The dust detection algorithm is only valid over ocean fields of regard. It should be useful for filtering data contaminated by dust, especially in the Saharan Air Layer (SAL) over the Atlantic Ocean. ***We recommend users ignore retrievals over oceans for which dust_score ≥ 380 or dust_flag = 1, regardless of the values of any QA indicators****.*

We also recommend that users filtering to select high quality data avoid AIRS fields of regard for which **BT_diff_SO2** ≤ 6 K. Those fields are likely contaminated by volcanic ash.

2.4 How IR-Only and Combined IR/MW Quality Control is Set Upon Completion of Final Retrieval

2.4.1 Preliminary Determinations

There are some preliminary determinations made which are then used to set the quality indicators. The first decision is between the final retrieval and the fallback state. The fallback state is chosen whenever the final retrieval fails to complete.

If the fallback case is selected, all IR-Only and Combined IR/MW quality indicators are set equal to 2, and none of the following logic is applied.

In V5, an internal variable **constituent_good** was determined using the predicted error of the water profile. In V6 and V7, this condition was replaced by a test requiring that the profile has Quality = 1 all the way to the surface (**PGood** = **PSurfStd**), leading to greater consistency in quality flagging between the total precipitable water and the water profile products.

The degrees of freedom for the CO (**CO_dof**) and CH_4 (**CH4_dof**) retrievals are used directly as outlined below. The residual for the CH_4 retrieval (**CH4_Resid_Ratio**, i.e., the ratio of the CH_4 residual to the expected noise) is also used in CH_4 quality control.

Limit checks are made to detect values far out of range of the range of validity of the Rapid Transmittance Algorithm (RTA) used for forward calculation of radiances from the physical state. Values of bad_<component> are flagged in the L2 Support Product if they are out of the validated RTA range by 25% or 50% of that range in log() space of the particular retrieved component.

- bad_temps - If 4 or more levels have temperatures 25% out of range, then bad_temps is set. Levels that are 50% out of range count double, so only two such are required to set bad_temps.

If the test on the temperature profile succeeds, then additional tests are carried out for each constituent. (See Appendix II for limits).

- bad_H2O and bad_O3 – set if 5 or more layers are 50% out
- soso_H2O and soso_O3 – set if 5 or more layers are 25% out or 1 or more layers are 100% out.

If either H2O or O3 is “bad”, then all constituents (but not temperature) are marked QC = 2. If either is “soso” then all constituent QC is initiated at QC=1.

If psurf or tsurf is 25% out of range then QC = 1 for all surface quantities.

The individual quality indicators are then set as follows for cases where the retrieval completes (combined IR/MW or IR-Only).

2.4.2 Temperature products

In V7, as in V6, there is a QC flag at every level reflecting whether the level is at an altitude above **PBest** (Quality = 0), between **PBest** and **PGood** (Quality = 1), or beneath **PGood** (Quality = 2) as discussed in the overview (Section 2.1). The profiles for which retrievals are not available are marked Quality = 2 at all levels.

Standard product:

TAirStd_QC = Profile Quality
TSurfAir_QC = Profile Quality(nSurfSup)
PTropopause_QC = Profile Quality(PTropopause + 50 mb)
T_Tropopause_QC = Proflile Quality(PTropopause + 50 mb)

Support product:

TairSup_QC = Profile Quality

2.4.3 Water Products

In V7, as in V6, there is a QC flag at every level reflecting whether the level is at an altitude above **PBest** (Quality = 0), between **PBest** and **PGood** (Quality = 1), or beneath **PGood** (Quality = 2), as discussed in the overview (Section 2.1). The profiles for which retrievals are not available are marked Quality = 2 at all levels.

Despite any quality flagging, we have very little sensitivity to water in the stratosphere. Water values above the 100 hPa level reflect climatological assumptions and contain no actual retrieved information.

Standard product:

H2OMMRStd_QC = Profile Quality
H2OMMRLevStd_QC = Profile Quality
H2OMMRSurf_QC = Profile Quality(nSurfSup)
totH2OStd_QC = Profile Quality(nSurfSup)
RelHum_QC = Profile Quality
RelHumSurf_QC = Profile Quality(nSurfSup)
RelHum_liquid_QC = Profile Quality
RelHumSurf_liquid_QC = Profile Quality(nSurfSup)
H2OMMRSat_QC = Profile Quality
H2OMMRSatLevStd_QC = Profile Quality
H2OMMRSatSurf_QC = Profile Quality(nSurfSup)
H2OMMRSat_liquid_QC = Profile Quality
H2OMMRSatLevStd_liquid_QC = Profile Quality

H2OMMRSatSurf_liquid_QC = Profile Quality(nSurfSup)
GP_Tropopause_QC = Profile Quality(nSurfSup)
GP_Height_QC = Profile Quality(nSurfSup)
GP_Surface_QC = Profile Quality(nSurfSup)

Support product:

H2OCDSup_QC = Profile Quality
H2OMMRLevSup_QC = Profile Quality
H2OMMRSatLevSup_QC = Profile Quality
H2OMMRSatLevSup_liquid_QC = Profile Quality
H2O_VMR_eff_QC = Profile Quality
GP_HeightSup_QC = Profile Quality(nSurfSup)

2.4.4 Surface Products

The surface quality **Qual_Surf** is set by testing the surface temperature error estimate, **TSurfStdErr** against a threshold.

Over Ocean:

Qual_Surf = 0 if **TSurfStdErr** < 1.1 K (1.2 K in AIRS-only)

Qual_Surf = 1
if Lat > -40° and **TSurfStdErr** < 1.4 K
if Lat < -60° and **TSurfStdErr** < 2.0 K
if -60° ≤ Lat ≤ -40° and **TSurfStdErr** < a value linearly interpolated in latitude from 1.4 K to 2.0 K

Qual_Surf = 2 if **TSurfStdErr** fails test

Over Land and Frozen Cases:

Qual_Surf = 1 if **PGood = PSurfStd** and **TSurfStdErr** < 7.0 K

Qual_Surf = 2 otherwise

Standard product:

TsurfStd_QC = Qual_Surf
emisIRStd_QC = Qual_Surf

Support product:

Emis50GHz_QC = Qual_Surf
Effective_Solar_Reflectance_QC = Qual_Surf

2.4.5 Geopotential Products

Geopotentials are calculated by integrating temperature and water vapor from the surface up. Therefore, no geopotential fields are good unless the quality of the profile is good all the way from the top of the atmosphere down to the surface. All **GP*_QC** are set equal to **TAirSurf_QC**, the quality of surface air temperature.

Standard product:

GP_Surface_QC = TAirSurf_QC
GP_Height_QC = TAirSurf_QC
GP_Tropopause_QC = TAirSurf_QC

Support product:

GP_Height_Sup_QC = TAirSurf_QC

2.4.6 Ozone Products

Ozone quality control was completely revised for V7 as described in Appendix I.

Because the ozone channels all see the surface, we do not in this version discriminate a “good” (Quality = 1) portion of the profile from a “best” (Quality = 0) portion of the profile; the entire profile is either Quality = 0 or Quality = 2.

Standard product:

totO3Std_QC
O3VMRStd_QC
O3VMRLevStd_QC
O3VMRSurf_QC

Support product:

O3CDSup_QC
O3VMRLevSup_QC
O3_VMR_eff_QC

2.4.7 Carbon Monoxide Products

If **PGood = PSurfStd**, and **CO_dof** > 0.5, then all CO products are marked Quality = 0.

If **PGood = PSurfStd**, and 0.5 >= **CO_dof** > 0.4, then all CO products are marked Quality = 1.

Otherwise, all CO products are marked Quality = 2.

Standard product:

CO_total_column_QC

COVMRLevStd_QC

COVMRSurf_QC

Support product:

COCDSup_QC

COVMRLevSup_QC

CO_VMR_eff_QC

2.4.8 Methane products

Initial QC tests:

If **PGood = PSurfStd** and **CH4_Resid_Ratio** < 1.5 and **CH4_dof** > 0.5, then all CH4 products are marked Quality = 0.

If **PGood = PSurfStd** and **CH4_Resid_Ratio** < 1.5 and 0.5 >= **CH4_dof** > 0.4, then all CH4 products are marked Quality = 1.

Otherwise, all CH4 products are marked Quality = 2.

Additional QC tests:

The CH4 absorption band is within the water vapor absorption band near 7.6 μm, and thus the quality of the moisture product impacts that of the CH4 product. Therefore, if **totH2OStd_QC** = 1, we set all CH_4 quality flags to 1 if:

- **CH4_Resid_Ratio** ≥ 1.0, or
- **PGood** ≤ 610 hPa

We found the contamination of CH_4 retrievals is mainly from low water clouds. Under the condition of **totH2OStd_QC** = 1, we set all CH_4 quality flags to 2 when the cloud fraction among the 9 AIRS spots within a retrieval FOV are mainly water clouds or they are very different. The test for water clouds uses **cloud_phase_3x3** (located in the L2 Support Product).

We recognize there remains a scan angle dependence of retrieved CH_4 at altitudes above the 200 hPa level in the tropics. To minimize its impact upon research, we set Quality=2 for the two most extreme san angle retrievals at the beginning and end of each scan set (i.e., retrieval FOVs 1, 2, 29 and 30) whenever **PTropopause** ≤ 100 hPa.

Standard product:

CH4_total_column_QC
CH4VMRLevStd_QC
CH4VMRSurf_QC

Support product:

CH4CDSup_QC
CH4VMRLevSup_QC
CH4_VMR_eff_10func_QC

2.4.9 CO2

The CO2 appearing in the L2 Support Product is not a retrieved quantity; rather, it is the first-guess CO_2 concentration (parts per million by volume) used during the Level 2 physical retrieval of other atmospheric parameters. **A subsequent algorithm ingests the Level 2 retrieval products and is initialized with the same first-guess CO_2 value to produce the AIRS CO_2 product separately.**

The first-guess value of the CO_2 concentration (parts per million by volume) is calculated for each footprint via the following algorithm:

$$CO2\_ppmv(t) = 371.789948 + 2.026214 \times \Delta t$$

Δt is the time between the current FOV and 0hr UT on Jan 1, 2002,

$$\Delta t = \left(t_{FOV} - t_{0UT\_01Jan02}\right)$$

and is expressed in fractions of a year. This linear fit to the marine GLOBALVIEW-CO2 from start of 2002 to end of 2009 is applied globally to avoid non-linear effects in the RTA calculation that could arise from very large differences between a fixed assumed and the true CO_2 concentration over the time span of the mission, while at the same time not introducing geospatial or seasonal variations that might leak into the post-processing CO_2 retrieval.

Support product:

CO2ppmv
CO2ppmv_QC

CO2ppmv_QC is always set to 2 in V7 to indicate that it is not a retrieved quantity.

2.4.10 Cloud and OLR products

For nearly all these products:

If we accept a final retrieval, Quality = 0.

If we accept a final retrieval, but the final retrieved surface temperature differs from the neural net surface temperature by > 5 K, the clouds and OLR are calculated from the neural net, and these values are set to Quality = 1.

In the event that the cloud retrieval is not completed this indicator is set to Quality = 2.

The clear sky OLR products require an accurate retrieval to the surface, so their QC are set as follows. If the profile quality is good to the surface (**PGood = PSurfStd**), the internal indicator, Qual_clrolr_QC is set to 0; otherwise this indicator is set to 2. The reported variables, **clrolr_QC** and **spectralclrolr_QC** are set equal to this indicator.

Cloud_phase_3x3 is a derived parameter, rather than a retrieved parameter and therefore does not have a _QC field associated with it. Instead, whenever the cloud phase cannot be determined the value of cloud_phase_3x3 is set to -9999 and the low bit of **cloud_phase_bits** is set. These are cases where QC indicates that required inputs were of low quality.

Reasons for cloud_phase_3x3 to be set to -9999 are:

1) QC=2 for surface emissivity
2) QC=2 for cloud fraction
3) All radiances = -9999 for all channels in any band.

Standard product:

CldFrcTot_QC
CldFrcStd_QC
PCldTop_QC
TCldTop_QC
PCldTopStd_QC
TCldTopStd_QC
olr_QC
olr3x3_QC
clrolr_QC (= Qual_clrolr)

Support product:

CldEmis_QC
CldRho_QC
IR_Precip_Est_QC
IR_Precip_Est3x3_QC
spectralolr_QC
spectralclrolr_QC (= Qual_clrolr)

2.4.11 Cloud Cleared Radiances

The channel-by-channel quality flags were new in V6 and unchanged for V7. The error estimates for each channel (**radiance_err**) are converted to brightness temperature error estimates, and the quality flags are then set as follows:

= 0 if $\Delta T < 1.0$ K
= 1 if $1.0 <= \Delta T < 2.5$ K
= 2 otherwise

Cloud-clearing product:

radiances_QC

2.4.12 QC Indicators for Other Products (in Support Product)

Support product:

Except as noted, all of these products require **PGood = PSurfStd** or they have Quality = 2.

bndry_lyr_top_QC is set to 0 unless:

1) If SurfClass is not 2 (nonfrozen ocean) then bndry_lyr_top_QC is set to 2
2) If a noncontiguous layer has a gradient over 97% of the value of the gradient for the chosen layer then bndry_lyr_top_QC = 1
3) If the relative humidity input to the calculation is < 0 or > 3 then bndry_lyr_top_QC = 1.
4) Bndr_lyr_top_QC is set never to be lower (better) than TSurfAir_QC.
5) If RelHumSUrf > 100% then bndry_lyr_top_QC = 2.

Course Climate Indicator (CCI) QC:

Tropo_CCI_QC

Strato_CCI_QC

These flags are set the same way as the total precipitable water flag; best if **PBest** is at the surface, else 1 if **PGood** is at the surface, else 2.

ice_cld_opt_dpth_QC

=0 if ice_cld_opt_dpth_ave_kern ≥ 0.8
and ice_cld_fit_reduced_chisq < 10.0

=1 if ice_cld_opt_dpth_ave_kern < 0.8 or ice_cld_fit_reduced_chisq ≥10.0

=2 if ice_cld_opt_dpth_ave_kern < 0.8
and ice_cld_fit_reduced_chisq ≥10.0

ice_cld_eff_diam_QC

=1 if ice_cld_eff_diam_ave_kern ≥ 0.8
and ice_cld_fit_reduced_chisq < 10.0

=2 if ice_cld_eff_diam_ave_kern < 0.8 or ice_cld_fit_reduced_chisq ≥ 10.0

=0 NEVER. We chose to make stricter quality control for the ice cloud effective diameter and no fields satisfy the criteria.

ice_cld_temp_eff_QC

=0 if ice_cld_temp_eff_ave_kern ≥ 0.8
and ice_cld_fit_reduced_chisq < 10.0

=1 if ice_cld_temp_eff_ave_kern < 0.8 or ice_cld_fit_reduced_chisq ≥10.0

=2 if ice_cld_temp_eff_ave_kern < 0.8
and ice_cld_fit_reduced_chisq ≥10.0

The following two parameters depend on L1B radiance quality instead of L2 quality flags:

BT_diff_dust_LR_QC

= 2 for bad L1B values in either primary band (830-835 cm^{-1}, 955-965 cm^{-1})

= 1 for bad L1B value in the secondary band (1219.5-1124 cm^{-1}), or land, or cold

= 0 otherwise

BT_diff_SO2_QC

= 2 if either L1B channel is bad

= 0 otherwise

2.4.13 Other QC Indicators

Standard product:

PsurfStd_QC

= 0 if surface pressure from timely forecast (normal)
= 1 if surface pressure from climatology/topography
= 2 only occurs if satellite is not in normal operations

This is not a retrieval quality flag, but instead reflects the input source of the surface pressure.

3 IR-Only and Combined IR/MW Retrieval Error Estimation

This section describes how errors are estimated for a given geophysical quantity and how the quality indicator pressure boundaries **PGood** and **PBest** are determined in detail, based on error estimates.

The following 14 quantities (also contained within the Level 2 Standard Product) are primarily indicative of values of different internal convergence tests. All differences are absolute values. They are used via regression to estimate errors in the surface temperature, air temperature profile at 100 levels, and the total water burden:

1.	**CC1_Resid**	fit parameter for first cloud clearing
2.	**CCfinal_Resid**	fit parameter for final cloud clearing
3.	**CCfinal_Noise_Amp**	amplification factor for SECOND cloud clearing
4.	**Surf_Resid_Ratio**	ratio of residual in surface retrieval to expected noise
5.	**Temp_Resid_Ratio**	ratio of residual in temperature retrieval to expected noise
6.	**CC1_noise_eff_amp_factor**	effective noise amplification factor in first cloud clearing
7.	**CC_noise_eff_amp_factor**	effective noise amplification factor in last cloud clearing
8.	**TSurfdiff_IR_4CC2**	difference between final Tsurf and that used in second cloud clearing.
9.	**TotCld_4_CCfinal**	cloud fraction from IR retrieval
10.	**Water_Resid_Ratio**	ratio of residual in water retrieval to expected noise
11.	**Tdiff_IR_4CC1**	difference in lowest 2 km between startup state and IR retrievals

Note that three predictors from V6 have been omitted in V7 since they depended on use of the AMSU channels.

The error estimate, $\delta \mathbf{x}_i$, for geophysical parameter ***i*** for a particular profile is:

$$\delta x_i = \sum_{k=1}^{11} M_{i,k} y_k$$

where $\boldsymbol{y_k}$ is the value of parameter ***k*** for a given case. There are separate matrices ***M*** for non-frozen ocean cases, land cases, and ice cases. The

coefficients of these matrices were trained on two full days of retrievals for 9/29/04 and 2/24/07 using the ECMWF 3-hour forecast for that day as “truth”.

Temperature error estimates at 6 levels (151 mb, 260 mb, 497 mb, 707 mb, 853 mb, 986 mb) and the total water error estimate are then used to predict errors via a second regression for water at 100 levels and for the cloud cleared radiances on a channel by channel basis. Since these seven predictors are themselves based only on the original 11 predictors and can be thought of as pseudo-principal components, these estimates are also based indirectly only on the original 11 predictors.

Error estimates for other quantities in the output files are either internal noise covariance estimates, varying by case, or ensemble error estimates, constant over all cases with a particular processing path. All error estimates are constrained not to fall beneath minimum values, and a few are constrained not to exceed impossibly high values.

A temperature error profile is defined by one of three cases, depending on the surface classification:

(O) Non-frozen ocean with liquid water covering >99% of FOV (**SurfClass** = 2)

(L) Land or coast cases (**SurfClass** = 0,1)

(F) Frozen cases, either land or ocean (**SurfClass** = 3,4,5,6,7)

The error profiles are defined by values at 70 mb, **PSurfStd**/2 (representative of the pressure at the middle of the atmosphere), and **PSurfStd**, and interpolated linearly in pressure to the 100 support levels. The values for determining **PBest** for the three cases are:

Case	**TAirStdErr @70mb**	**TAirStdErr @PSurfStd/2**	**TAirStdErr @PsurfStd**
O	3.0 K	1.25 K	1.5 K
L	3.0 K	1.25 K	1.5 K
F	3.0 K	1.25 K	1.5 K

A pressure level **PBest** is then set by comparing the temperature quality profiles with the level-by-level error estimates (at 100 levels) beginning downward from 70 mb. If the error estimate exceeds the quality profile for eight consecutive levels above 300 mb or three consecutive levels beneath 300 mb, **PBest** is set to the level above the first of those consecutive levels.

The values for determining **PGood** for the three cases are:

Case	TAirStdErr @70mb	TAirStdErr @PSurfStd/2	TAirStdErr @PsurfStd
O	3.25 K*	3.5 K*	3.25 K*
L	3.25 K*	2.0 K*	2.0 K*
F	3.25 K*	2.75 K*	3.75 K*

*3.0 K in AIRS/AMSU and AIRS/AMSU/HSB systems

A pressure level **PGood** is then set by comparing the temperature quality profiles with the level-by-level error estimates (at 100 levels) beginning downward from 70 mb. If the error estimate exceeds the quality profile for eight consecutive levels above 300 mb or three consecutive levels beneath 300 mb, **PGood** is set to the level above the first of those consecutive levels. The thresholds for **PGood** are always looser than for **PBest**, so **PGood** will occur at a pressure deeper than or equal to **PBest**.

4 Appendix I – Quality Indicator Changes for V7

Several modifications have been made to the temperature and water vapor quality control between Version 6 and Version 7. They are not conceptual changes but have been designed to improve the quality of the retrieval in the boundary layer by better discriminating among cases.

- The error estimate used as the decision point for atmospheric temperature and water profile QCs is moved from 6 layers above the surface in V6 to 2 layers above the surface over frozen and land surfaces in V7. This effectively uses the entire profile error estimate information and allows the algorithm to make finer distinctions of quality over land and frozen areas near the surface. The decision point for land surface temperature remains at 6 levels above the surface.

- The numerical threshold points for marking profile levels with QC=2 is tightened over land from the mid to lower atmosphere, and for frozen cases in the middle atmosphere, while the numerical threshold for frozen cases near the surface is slightly loosened which increases the yield over frozen surfaces.

- One relative humidity quality check was modified. In V6, cases with unrealistic relative humidity and low cloud fractions are identified and the profiles are marked as QC=2 up to 100hPa. In V7 this test is revised to address the uncertainty associated with the cloud top pressure in a less restrictive way by moving Pgood and Pbest only a few levels instead of to 100hPa.

- Ozone in V7 now has its own quality control. Ozone retrievals are marked 2 (do not use) if any of the following conditions occurred. These tests reduce the overall Level 2 yield by 10-15% and eliminate most spurious results. However, only rarely do noticeable gaps result in the Level 3 gridded product.

    a) If the attempted change on the first iteration is too large. The temperature or water profiles may have large errors, and the ozone retrieval may try to fix them with a spurious ozone profile
    b) If radiative closure is not achieved in the ozone channels. This usually happens because the surface temperature is grossly in error, and off-diagonal elements in the noise covariance matrix correctly reflect this, but the ozone retrieval is still poor in these cases.
    c) If the UMBC dust test indicates the presence of significant dust. Over both land and ocean these retrievals can be erroneous.
    d) If the change in emissivity from the first guess is very different in the ozone spectral region and the adjacent spectral regions. This test identifies some spurious retrievals missed by the dust test.

V7 continues the V6 pattern that each retrieved physical quantity now has its own matching quality indicator and error estimate. The names of the quality indicators

are the same as the name of the corresponding parameter with "_QC" appended to the name. The meaning of QC values 0, 1 and 2 are unchanged from what they were in V6. The error estimates continue the V5 and V6 convention of having the name of the parameter with "Err" appended, for example an array named **TAirStdErr**. The marking of temperature and water profiles by **PBest** and **PGood** continues as in V6.

5 Appendix II – Limit Check Bounds

Minumum PSurfStd = 490 hPa
Maximum PSurfStd = 1100 hPa

Minimum TSurfStd = 160 K
Maximum TSurfStd = 360 K

Level PressSupp (hPa)	MIN Tprof K	MAX Tprof K	MIN H2OCDSup cm^{-2}	MAX H2OCDSup cm^{-2}	MIN O3CDSup cm^{-2}	MAX O3CDSup cm^{-2}	MIN COCDSup cm^{-2}	MAX COCDSup cm^{-2}	MIN CH4CDSup cm^{-2}	MAX CH4CDSup cm^{-2}
0.0161	149.1	231.9	1.93E+14	1.54E+15	3.12E+13	2.06E+14	2.30E+14	7.02E+14	3.21E+13	4.56E+13
0.0384	160.7	243	3.88E+14	3.04E+15	5.56E+13	4.78E+14	1.45E+14	5.75E+14	6.42E+13	9.09E+13
0.0769	171.2	252.9	6.68E+14	5.50E+15	1.19E+14	9.00E+14	1.27E+14	5.97E+14	1.10E+14	1.55E+14
0.137	184	258.5	1.04E+15	9.15E+15	3.41E+14	1.72E+15	1.22E+14	5.93E+14	1.71E+14	2.41E+14
0.2244	204	264.6	1.51E+15	1.40E+16	7.20E+14	3.39E+15	1.10E+14	5.83E+14	2.41E+14	3.59E+14
0.3454	214.2	268.7	2.09E+15	2.01E+16	1.46E+15	6.74E+15	1.03E+14	6.25E+14	3.54E+14	5.25E+14
0.5064	212.2	273.8	2.78E+15	2.75E+16	2.58E+15	1.24E+16	1.06E+14	6.40E+14	5.12E+14	7.52E+14
0.714	210	279.2	3.58E+15	3.58E+16	4.29E+15	2.04E+16	1.17E+14	6.06E+14	7.26E+14	1.12E+15
0.9753	207.1	282	4.51E+15	4.50E+16	5.93E+15	3.10E+16	1.31E+14	5.81E+14	9.63E+14	1.67E+15
1.2972	203.6	282.7	5.55E+15	5.54E+16	8.28E+15	4.41E+16	1.46E+14	5.77E+14	1.33E+15	2.52E+15
1.6872	200.4	280.7	6.72E+15	6.71E+16	1.17E+16	6.05E+16	1.59E+14	6.37E+14	1.91E+15	3.85E+15
2.1526	198.7	278.9	8.01E+15	8.00E+16	1.44E+16	8.35E+16	1.70E+14	7.06E+14	2.69E+15	5.69E+15
2.7009	198.2	280.5	9.43E+15	9.42E+16	1.75E+16	1.12E+17	1.77E+14	7.64E+14	3.68E+15	7.94E+15
3.3398	200.6	281.7	1.10E+16	1.10E+17	2.10E+16	1.47E+17	1.77E+14	8.08E+14	4.98E+15	1.05E+16
4.077	205.3	279.9	1.27E+16	1.27E+17	2.55E+16	1.87E+17	1.79E+14	8.50E+14	6.55E+15	1.35E+16

Level PressSupp (hPa)	MIN Tprof K	MAX Tprof K	MIN H2OCDSup cm^{-2}	MAX H2OCDSup cm^{-2}	MIN O3CDSup cm^{-2}	MAX O3CDSup cm^{-2}	MIN COCDSup cm^{-2}	MAX COCDSup cm^{-2}	MIN CH4CDSup cm^{-2}	MAX CH4CDSup cm^{-2}
4.9204	209.1	277.4	1.45E+16	1.45E+17	3.07E+16	2.32E+17	1.83E+14	8.99E+14	8.39E+15	1.72E+16
5.8776	211.2	275.1	1.64E+16	1.64E+17	3.85E+16	2.80E+17	1.91E+14	9.56E+14	1.02E+16	2.14E+16
6.9567	208.7	273.3	1.85E+16	1.85E+17	5.03E+16	3.21E+17	2.03E+14	1.02E+15	1.22E+16	2.61E+16
8.1655	203.7	268.2	2.07E+16	2.07E+17	6.37E+16	3.57E+17	2.16E+14	1.09E+15	1.44E+16	3.14E+16
9.5119	200.6	259.5	2.31E+16	2.31E+17	7.88E+16	3.93E+17	2.34E+14	1.16E+15	1.68E+16	3.72E+16
11.0038	197.8	251.9	2.56E+16	2.56E+17	9.22E+16	4.28E+17	2.53E+14	1.22E+15	1.96E+16	4.35E+16
12.6492	195.2	250.3	2.82E+16	2.82E+17	1.02E+17	4.49E+17	2.69E+14	1.29E+15	2.27E+16	5.00E+16
14.4559	192.7	249.3	3.10E+16	3.09E+17	1.10E+17	4.49E+17	2.87E+14	1.35E+15	2.61E+16	5.62E+16
16.4318	190.4	248.3	3.39E+16	3.38E+17	1.19E+17	4.84E+17	3.07E+14	1.41E+15	2.96E+16	6.28E+16
18.5847	189.4	247.6	3.69E+16	3.68E+17	1.21E+17	5.17E+17	3.25E+14	1.48E+15	3.32E+16	6.98E+16
20.9224	190.2	247	4.00E+16	4.00E+17	1.24E+17	5.50E+17	3.47E+14	1.55E+15	3.70E+16	7.73E+16
23.4526	190.9	246.4	4.33E+16	4.33E+17	1.26E+17	5.70E+17	3.69E+14	1.62E+15	4.09E+16	8.52E+16
26.1829	189.3	245.8	4.68E+16	4.68E+17	9.78E+16	5.85E+17	3.94E+14	1.70E+15	4.51E+16	9.35E+16
29.121	187.8	245.3	5.03E+16	5.19E+17	7.79E+16	5.93E+17	4.37E+14	1.79E+15	4.97E+16	1.02E+17
32.2744	186.5	244.7	5.40E+16	5.74E+17	7.36E+16	6.06E+17	4.77E+14	1.89E+15	5.58E+16	1.10E+17
35.6505	185.2	244.2	5.78E+16	6.22E+17	4.41E+16	6.32E+17	5.10E+14	2.04E+15	6.25E+16	1.18E+17
39.2566	184.5	243.8	6.17E+16	6.71E+17	9.92E+15	6.52E+17	5.39E+14	2.20E+15	6.98E+16	1.28E+17
43.1001	184.8	243.9	6.57E+16	7.23E+17	5.03E+15	6.46E+17	5.72E+14	2.38E+15	7.76E+16	1.38E+17
47.1882	185.5	244	6.99E+16	7.77E+17	3.31E+15	6.34E+17	6.09E+14	2.57E+15	8.62E+16	1.48E+17
51.5278	186.1	243.5	7.42E+16	8.33E+17	2.95E+15	6.18E+17	6.67E+14	2.82E+15	9.57E+16	1.61E+17
56.126	186.7	242.8	7.86E+16	9.03E+17	3.00E+15	5.99E+17	7.35E+14	3.10E+15	1.06E+17	1.75E+17
60.9895	187.3	241.9	8.31E+16	9.79E+17	3.11E+15	5.87E+17	8.34E+14	3.47E+15	1.17E+17	1.90E+17
66.1253	187.9	240.6	8.78E+16	1.13E+18	3.28E+15	5.90E+17	9.65E+14	3.95E+15	1.29E+17	2.04E+17
71.5398	188.5	239.2	9.25E+16	1.49E+18	3.46E+15	5.90E+17	1.08E+15	4.46E+15	1.41E+17	2.20E+17
77.2396	189	238	9.74E+16	2.10E+18	3.65E+15	5.90E+17	1.20E+15	5.08E+15	1.54E+17	2.36E+17

Level PressSupp (hPa)	MIN Tprof K	MAX Tprof K	MIN H2OCDSup cm^{-2}	MAX H2OCDSup cm^{-2}	MIN O3CDSup cm^{-2}	MAX O3CDSup cm^{-2}	MIN COCDSup cm^{-2}	MAX COCDSup cm^{-2}	MIN CH4CDSup cm^{-2}	MAX CH4CDSup cm^{-2}
83.231	189.6	237.8	1.02E+17	2.83E+18	4.08E+15	5.86E+17	1.35E+15	5.76E+15	1.66E+17	2.51E+17
89.5204	190.2	237.6	1.07E+17	3.63E+18	4.59E+15	5.82E+17	1.53E+15	6.60E+15	1.78E+17	2.66E+17
96.1138	190.8	237.4	1.13E+17	4.65E+18	5.08E+15	5.74E+17	1.77E+15	7.97E+15	1.88E+17	2.80E+17
103.017	191.3	237.1	1.18E+17	5.75E+18	5.07E+15	5.66E+17	2.06E+15	9.74E+15	1.99E+17	2.93E+17
110.237	191.9	236.7	1.23E+17	7.09E+18	5.92E+15	5.55E+17	2.42E+15	1.20E+16	2.11E+17	3.09E+17
117.777	192.5	236.2	1.29E+17	9.36E+18	1.13E+16	5.42E+17	2.84E+15	1.50E+16	2.22E+17	3.25E+17
125.646	193	235.7	1.34E+17	1.19E+19	1.01E+16	5.28E+17	3.34E+15	1.85E+16	2.34E+17	3.41E+17
133.846	193.5	235.2	1.40E+17	1.47E+19	8.42E+15	5.12E+17	3.86E+15	2.25E+16	2.46E+17	3.58E+17
142.385	193.8	234.8	1.46E+17	1.99E+19	7.41E+15	4.94E+17	4.43E+15	2.69E+16	2.58E+17	3.75E+17
151.266	194	234.3	1.52E+17	2.62E+19	7.21E+15	4.73E+17	5.08E+15	3.16E+16	2.70E+17	3.92E+17
160.496	194.1	234.5	1.57E+17	3.28E+19	7.20E+15	4.56E+17	5.59E+15	3.65E+16	2.82E+17	4.08E+17
170.078	194.1	235.3	1.63E+17	4.09E+19	6.78E+15	4.48E+17	6.13E+15	4.17E+16	2.93E+17	4.25E+17
180.018	193.8	236.2	1.70E+17	5.18E+19	6.52E+15	4.40E+17	6.78E+15	4.70E+16	3.05E+17	4.42E+17
190.32	193.5	237	1.76E+17	6.32E+19	6.15E+15	4.30E+17	7.47E+15	5.24E+16	3.18E+17	4.60E+17
200.989	193.4	237.8	1.82E+17	7.52E+19	5.47E+15	4.19E+17	8.18E+15	5.79E+16	3.30E+17	4.78E+17
212.028	195.1	238.6	2.15E+17	9.10E+19	5.24E+15	3.93E+17	8.95E+15	6.33E+16	3.42E+17	4.95E+17
223.441	198	240.9	2.69E+17	1.10E+20	5.35E+15	3.54E+17	9.66E+15	6.85E+16	3.55E+17	5.13E+17
235.234	200.9	244.3	3.25E+17	1.33E+20	5.47E+15	3.28E+17	1.02E+16	7.34E+16	3.67E+17	5.31E+17
247.408	202.2	247.5	3.83E+17	1.60E+20	5.59E+15	3.08E+17	1.07E+16	7.80E+16	3.80E+17	5.49E+17
259.969	203.4	250.2	4.65E+17	1.92E+20	5.70E+15	2.88E+17	1.12E+16	8.23E+16	3.93E+17	5.67E+17
272.919	205.2	252.1	5.97E+17	2.29E+20	5.81E+15	2.66E+17	1.16E+16	8.62E+16	4.06E+17	5.85E+17
286.262	207	254	7.36E+17	2.72E+20	5.91E+15	2.44E+17	1.21E+16	8.98E+16	4.19E+17	6.03E+17
300	208.8	255.6	8.79E+17	3.24E+20	5.82E+15	2.22E+17	1.25E+16	9.32E+16	4.32E+17	6.21E+17
314.137	210.6	257	8.56E+17	3.75E+20	5.75E+15	1.98E+17	1.31E+16	9.66E+16	4.45E+17	6.40E+17
328.675	212.3	257.6	7.49E+17	4.48E+20	5.76E+15	1.74E+17	1.36E+16	9.98E+16	4.59E+17	6.58E+17

Level PressSupp (hPa)	MIN Tprof K	MAX Tprof K	MIN H2OCDSup cm^{-2}	MAX H2OCDSup cm^{-2}	MIN O3CDSup cm^{-2}	MAX O3CDSup cm^{-2}	MIN COCDSup cm^{-2}	MAX COCDSup cm^{-2}	MIN CH4CDSup cm^{-2}	MAX CH4CDSup cm^{-2}
343.618	213.1	258.1	6.26E+17	5.86E+20	5.79E+15	1.49E+17	1.66E+16	1.05E+17	4.72E+17	6.77E+17
358.966	213.9	258.5	6.43E+17	7.40E+20	5.81E+15	1.25E+17	1.86E+16	1.14E+17	4.86E+17	6.95E+17
374.724	214.7	259	7.59E+17	9.50E+20	5.83E+15	1.13E+17	1.97E+16	1.25E+17	4.99E+17	7.14E+17
390.893	215.4	259.6	8.78E+17	1.17E+21	5.84E+15	1.07E+17	2.08E+16	1.35E+17	5.13E+17	7.33E+17
407.474	215.9	260.5	9.93E+17	1.40E+21	5.85E+15	1.04E+17	2.20E+16	1.46E+17	5.27E+17	7.51E+17
424.47	216.4	261.3	1.11E+18	1.60E+21	5.86E+15	9.99E+16	2.32E+16	1.57E+17	5.41E+17	7.70E+17
441.882	217.3	263.1	1.29E+18	1.83E+21	5.86E+15	9.62E+16	2.45E+16	1.67E+17	5.54E+17	7.89E+17
459.712	218.5	265	1.53E+18	2.13E+21	5.86E+15	9.20E+16	2.58E+16	1.78E+17	5.68E+17	8.08E+17
477.961	219.7	267	1.93E+18	2.44E+21	5.86E+15	8.79E+16	2.71E+16	1.88E+17	5.82E+17	8.27E+17
496.63	220.8	268.9	2.87E+18	2.75E+21	5.91E+15	8.34E+16	2.83E+16	1.98E+17	5.96E+17	8.46E+17
515.72	222	270.7	6.31E+18	3.10E+21	5.68E+15	7.89E+16	2.96E+16	2.08E+17	6.10E+17	8.65E+17
535.232	223.2	272.2	9.53E+18	3.44E+21	5.42E+15	7.41E+16	3.09E+16	2.18E+17	6.24E+17	8.84E+17
555.167	224.7	273.8	1.06E+19	3.79E+21	5.30E+15	6.91E+16	3.21E+16	2.28E+17	6.38E+17	9.03E+17
575.525	226.2	275.3	1.17E+19	4.16E+21	5.16E+15	6.41E+16	3.33E+16	2.42E+17	6.52E+17	9.24E+17
596.306	227.9	276.8	1.32E+19	4.72E+21	4.86E+15	5.87E+16	3.46E+16	2.58E+17	6.66E+17	9.49E+17
617.511	229.6	279.5	1.49E+19	5.34E+21	4.53E+15	5.32E+16	3.58E+16	2.74E+17	6.80E+17	9.73E+17
639.14	231.4	283.6	1.65E+19	5.96E+21	4.37E+15	4.75E+16	3.70E+16	2.92E+17	6.94E+17	9.97E+17
661.192	233	287.5	1.82E+19	6.60E+21	4.28E+15	4.42E+16	3.83E+16	3.09E+17	7.08E+17	1.02E+18
683.667	234.1	290.9	1.96E+19	7.22E+21	4.27E+15	4.25E+16	3.95E+16	3.27E+17	7.22E+17	1.04E+18
706.565	235	293.9	2.14E+19	8.01E+21	4.14E+15	3.92E+16	3.69E+16	3.45E+17	7.37E+17	1.07E+18
729.886	236.2	297.2	2.33E+19	8.97E+21	4.07E+15	3.85E+16	3.68E+16	3.63E+17	7.50E+17	1.09E+18
753.628	237.2	300.9	2.53E+19	9.69E+21	4.01E+15	3.87E+16	3.72E+16	3.81E+17	7.64E+17	1.11E+18
777.79	238.2	304.8	2.82E+19	1.03E+22	3.86E+15	3.90E+16	3.75E+16	3.99E+17	7.78E+17	1.13E+18
802.371	238.7	309	3.13E+19	1.09E+22	3.76E+15	3.92E+16	3.83E+16	4.16E+17	7.92E+17	1.15E+18
827.371	239.2	312.5	3.45E+19	1.15E+22	3.73E+15	3.93E+16	4.19E+16	4.32E+17	8.06E+17	1.17E+18

Level PressSupp (hPa)	MIN Tprof K	MAX Tprof K	MIN H2OCDSup cm^{-2}	MAX H2OCDSup cm^{-2}	MIN O3CDSup cm^{-2}	MAX O3CDSup cm^{-2}	MIN COCDSup cm^{-2}	MAX COCDSup cm^{-2}	MIN CH4CDSup cm^{-2}	MAX CH4CDSup cm^{-2}
852.788	239.8	311.1	3.81E+19	1.31E+22	3.78E+15	3.94E+16	4.42E+16	4.48E+17	8.20E+17	1.19E+18
878.62	240.3	310	4.39E+19	1.49E+22	3.84E+15	3.95E+16	4.65E+16	4.63E+17	8.35E+17	1.21E+18
904.866	240.2	310	5.01E+19	1.68E+22	3.89E+15	3.95E+16	4.69E+16	4.76E+17	8.49E+17	1.22E+18
931.524	239.6	310	5.80E+19	1.89E+22	3.90E+15	3.95E+16	4.72E+16	4.88E+17	8.63E+17	1.24E+18
958.591	239.1	310	5.47E+19	2.16E+22	3.84E+15	3.92E+16	4.75E+16	4.99E+17	8.78E+17	1.25E+18
986.067	238.6	310	4.92E+19	2.46E+22	3.73E+15	3.94E+16	4.77E+16	5.09E+17	8.92E+17	1.27E+18
1013.95	238.2	310	4.37E+19	2.77E+22	3.62E+15	3.97E+16	4.78E+16	5.17E+17	9.07E+17	1.29E+18
1042.23	237.8	310.7	3.81E+19	3.08E+22	3.61E+15	4.00E+16	4.80E+16	5.23E+17	9.22E+17	1.31E+18
1070.92	237.4	313.4	3.24E+19	3.39E+22	3.65E+15	4.10E+16	4.81E+16	5.27E+17	9.36E+17	1.33E+18
1100	237.1	316	2.66E+19	3.71E+22	3.70E+15	4.50E+16	4.83E+16	5.30E+17	9.45E+17	1.36E+18